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Use of Satellite Data in East Coast Snowstorm Forecasting

FRANCES C. PARMENTER

NOAA TECHNICAL MEMORANDA

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USE OF SATELLITE DATA IN EAST COAST SNOWSTORM FORECASTING

Frances C. Parmenter

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USE OF SATELLITE DATA IN EAST COAST SNOWSTORM FORECASTING

Frances C. Parmenter
National Environmental Satellite Service

ABSTRACT. Numerous investigators have studied the forecasting problems surrounding East Coast cyclogenesis. This report describes some of the satellite-observed cloud features which can be used to detect areas of cyclogenesis and areas of heavy precipitation within these coastal storms.

INTRODUCTION

Accurate forecasting of the onset and subsequent accumulation of snow along the East Coast has long been a problem. The potential economic impact of a heavy snowstorm in the major cities of the northeastern United States is comparable, at least, to that of a hurricane threat. Many investigators have studied the problem and developed objective techniques for forecasting precipitation from these winter coastal storms. Forecast parameters such as sea-level cyclone tracks were studied by Penn (1948), Brooks and Schell (1950), Whiting and Stakely (1958), Hoover (1960), Bailey (1960), and Donaldson and Shafer (1965). McClain and Whitney (1965) compared aircraft and early TIROS satellite data for an East Coast cyclone. More recently, Spar (1967, 1968, 1970) has studied the three basic problems of local snowstorm forecasting: prediction of the start of precipitation, rain versus snow occurrence, and the snow accumulation rate for the New York City area.

It is agreed that the key to accurate snow prediction lies in the initial detection and correct forecasting of coastal cyclogenesis. These storms often begin as small secondary offshore developments that deepen rapidly and then quickly move northward. Aircraft and surface observations are often too sparse to completely define the size and intensity of these storms. Initially, these secondary cyclones are below the resolving power of the National Meteorological Center (NMC) numerical analysis grid. As a result, analysis and guidance materials for these situations are often inadequate.

In the conclusion of their report on forecasting these coastal storms, Spar, Brandes, and Grillo (1970) noted that, "If such (synoptic heavy snow-producing) patterns exist and can be recognized 24 or even 12 hours in advance of a heavy snowfall, they would obviously be of significant value to forecasters. Even patterns coincident with the beginning time of heavy snowfalls or shortly thereafter would be useful if accurate pattern prognostications were available."

Today, photographs from both polar-orbiting and geostationary satellites supplement the conventional surface, upper air, and aircraft reports available to the forecaster. The TIROS Operational Satellite (TOS) System provides worldwide daily coverage by means of visible and infrared observations. Two geostationary Applications Technology Satellites (ATS) also provide continuous daytime coverage over much of the earth. In the future, the Geostationary Operational Environmental Satellite (GOES) will provide frequent-interval IR and visible pictures of the Americas and adjacent coastal areas.

Many synoptic and mesoscale weather systems can be detected in the present satellite data. Methods for interpretation of satellite-observed cloud features and patterns have been described by many meteorologists, most recently by Anderson et al. (1969). The interpretation and meteorological analysis of these data have also been discussed recently by Oliver and Bittner (1970), and Nagle and Hayden (1971).

This report summarizes the possible contributions which the satellite observations can make toward a solution to the problem of forecasting East Coast snowstorms. For example, satellite data can be used to:

1. Locate areas where East Coast cyclone development is occurring;

2. Track the storm systems;

3. Assess the stage of storm development;

4. Define the significant weather areas of the storm, and delineate the area of heaviest precipitation; and

5. Predict the end of the heaviest precipitation.

DATA

The first polar-orbiting satellites of the TOS system were launched in 1966. This system included an Automatic Picture Transmission (APT) satellite that provided early morning (0900 LST) coverage and an Advanced Vidicon Camera System (AVCS)-equipped satellite that provided afternoon (1500 LST) coverage. The cases used in this study were selected from this period of dual satellite coverage. During the period from October 1966 through March 1969, there were 15 cases of East Coast storms[1] that resulted in a heavy[2] snowfall along the East Coast.

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1 The East Coast storm situation was defined as a situation where the system formed in the southern states, moved northward along the coast and then deepened offshore.

2 The National Weather Service generally defines "heavy snow" as a fall of at least four inches in 12 hours or six inches in 24 hours.

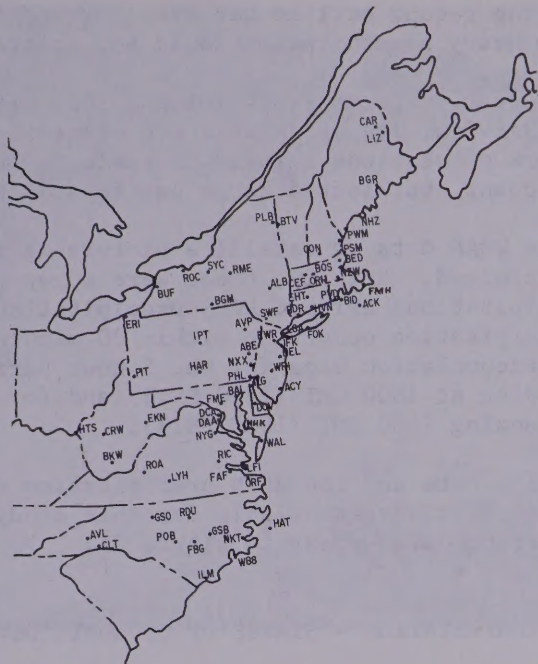

Figure 1. East Coast observing stations.

The storms investigated are listed below.

December 13-14, 1966
December 23-25, 1966
February 6-8, 1967
February 9-10, 1967
March 5-7, 1967
December 28-29, 1967
January 14-16, 1968
January 24-26, 1968
February 29-March 2, 1968
November 9-11, 1968
November 11-13, 1968
December 14-16, 1968
February 8-10, 1969
February 23-27, 1969
March 1-4, 1969

PROCEDURE

Many investigators, such as Bailey (1960) and Spiegler and Fisher (1970) found that the heaviest precipitation usually is located in the northwest quadrant of the low. Studies of satellite data have shown that the significant precipitation usually is associated with an area of convective clouds, and that the cloud vortex pattern marks the center of positive relative vorticity of the storm system. Thus, the satellite data for the storms listed above were examined for possible recurring cloud and precipitation patterns.

The APT and AVCS pictures for these dates were assembled. In some cases, pictures from two adjacent passes, taken two hours apart, covered the area of interest. (The data available for these dates are listed in table 1 in the appendix.) Two areas were outlined on the satellite data: the first outline included the area where precipitation of any type (showers to heavy precipi-

tation) would be found; the second outline was drawn around the convective clouds where moderate to heavy precipitation would be expected.

Surface Weather Observation Forms (WBAN 10A and 10B) were obtained for the 77 National Weather Service, Navy, and Air Force observing stations shown in figure 1. This network of stations (listed in table 2, Appendix) provided good coverage along the coast but left a large gap toward the mountains.

Maps summarizing the WBAN data at satellite picture-taking time were prepared for each case examined. Briefly, these were a map showing the times of onset and end of precipitation; APT and AVCS precipitation maps showing the heaviest type of precipitation occurring within 30 minutes of picture time; and precipitation accumulation maps for the 6-hour period preceding the average picture time (ending at 1800 GMT (1300 EST)) and for the 6-hour period after the picture time (ending 2400 GMT (1900 EST)).

The analyzed satellite data and the WBAN precipitation data maps were then compared. Some radar data were available for this study. Combined radar, satellite, and surface data appear in figure 11.

SATELLITE DATA INTERPRETATION - STAGES OF CYCLONIC DEVELOPMENT

Winter cyclones of the East Coast begin as small disturbances that form on, and move eastward or northeastward along, a front. Initially, the weak surface low is characterized by a large area of cloudiness in the Gulf States. This cloudiness may be, in order of increasing development, an unorganized, multilayered cloud band (S-T, figure 2a), a frontal wave characterized by a bulge of the frontal clouds toward the cold air (U, figure 2b), or a pattern with the initial characteristics of a vortex (figure 2c).

Cyclonic development along a front begins with the broadening of the cloud band. The clouds along the cold air side of the front will form a convex bulge (U, figure 2b) toward the cold air. The surface position of the wave is located under the bulge near where the curvature of the clouds changes from concave to convex (W, figure 2b). As the wave develops, the curvature of the bulge becomes more pronounced, the back edge of the higher clouds becomes more concave, and a lower, less solid cloud layer (X, figure 2b) appears along the cold air side of the cloud system.

As the system occludes, the cloud pattern forms a definite spiral. The frontal band curves into a vortex center and a well defined, relatively cloud-free dry slot (see page 3-A-6, Anderson et al. 1969) begins to form in the cold air between the vortex center and the frontal band. The frontal system in figure 2c is in the early stage of occlusion. The frontal band (S) curves into a center near T, and the dry slot (V), which has begun to form between the front and the vortex, is relatively cloud-free.

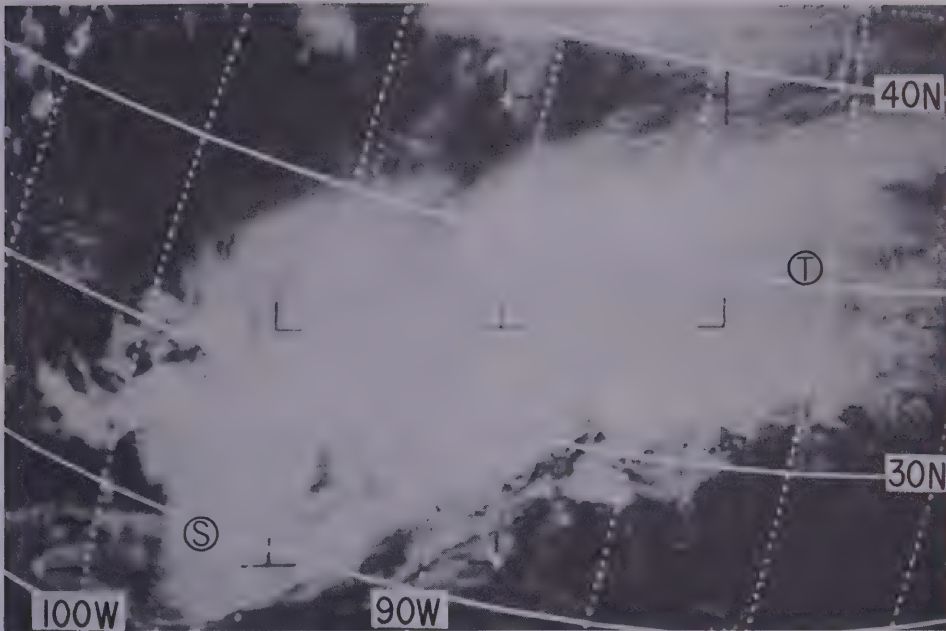

Figure 2a. ESSA-3, Orbit 1599, 1929 GMT, February 6, 1967. A NE-SW cloud band in the southeastern United States. NOTE: ESSA-3, Orbit 1599, 1929 GMT, identifies the satellite (ESSA-3), the orbit number (1599), and the time of picture taking (1929 GMT).

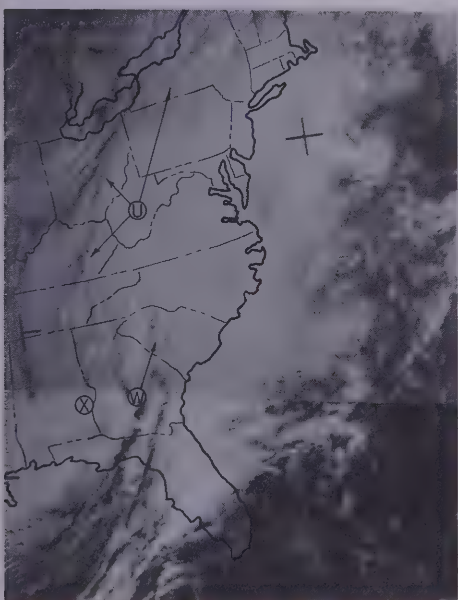

Figure 2b. ESSA-4, Orbit 600, 1450 GMT, December 28, 1967. Wave development in mid-Atlantic States.

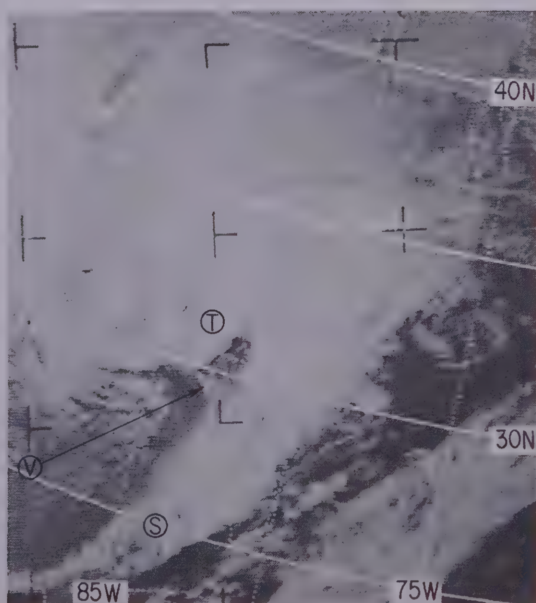

Figure 2c. ESSA-7, Orbit 1093, 1933 GMT, November 11, 1968. Occluding stage of an East Coast cyclone.

When the dry slot has reached the center of the vortex, the influx of moisture necessary for further development has been terminated and the cyclone has reached its mature stage. Most East Coast snowstorms are located as far north as Long Island by the time this mature stage has been reached. Figure 3 shows the cloud pattern associated with the mature stage of the March 1, 1968, snowstorm. Note that the dry slot (D-E-F) makes almost two revolutions about the vortex center.

As the storm begins to dissipate, cloud-free areas begin to appear in the middle- and low-level cumuliform cloud bands. These remaining spiral cloud patterns are often poorly organized and are often separated from the frontal band.

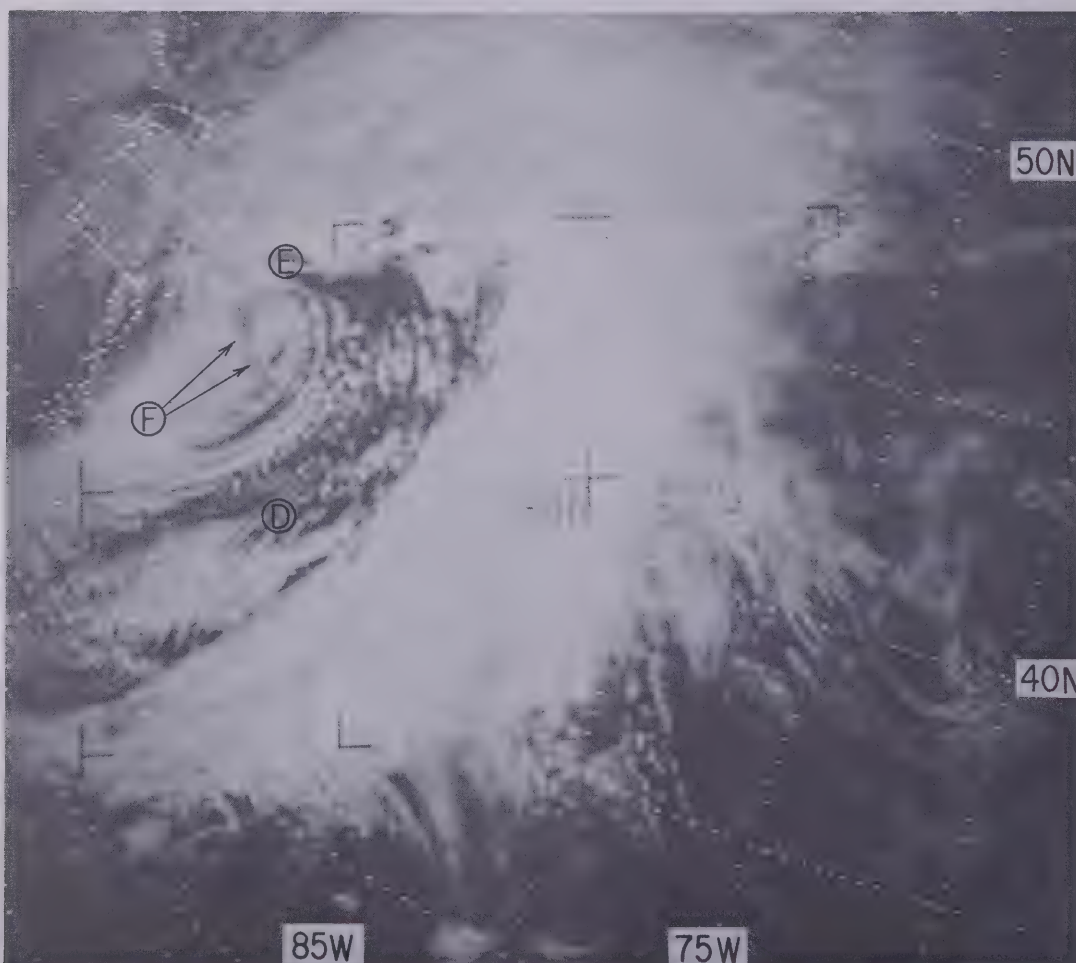

Figure 3. ESSA-3, Orbit 6483, 1743 GMT, March 1, 1968. Mature stage of an East Coast cyclone.

In most of the cases studied, the satellite-observed mature storm had a classical cloud pattern with a clear-cut jet axis position (arrows) shown in figure 4; the cloud vortex center is located at X, the frontal band extends from this center to S, and the dry slot is located along the cold air side of the front.

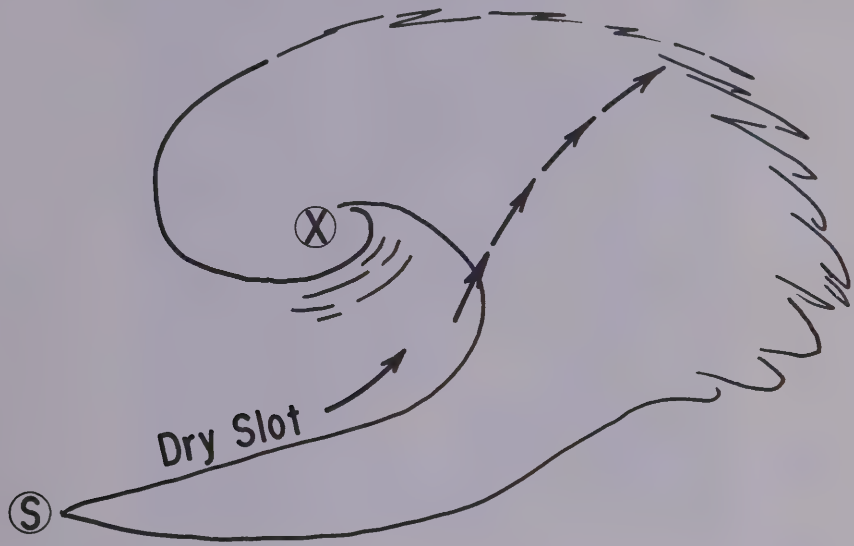

Figure 4. Schematic of a classical vortex cloud pattern associated with a mature vortex.

RESULTS

Determining Heavy Precipitation Areas

In the case of an East Coast snowstorm, the southern or trailing portion of the front (R-S, figure 5) normally will remain well offshore; significant precipitation will occur in the northern or east-west portion (T-X) of the storm system. Moderate to heavy precipitation (rain or snow) is found in the area of convective clouds (hatched area) west of the jet stream axis (arrows). Showers and light precipitation are found within the dashed line area.

These precipitation areas are determined in the following manner: The dashed line which encloses the general area of precipitation is drawn along the edge of the bright multilayered clouds. Care must be taken not to include the thin cirrus clouds which extend beyond the main vortex cloudiness. The resulting precipitation area is usually "kidney-shaped" and is located in the northern or east-west portion of the vortex. Looking downstream, the heaviest precipitation area (solid line) is located to the left of the jet stream. To draw the outline of the heavy precipitation, start near the jet stream axis (W, figure 5), continue along the southern portion of the solid clouds just north of the dry slot, curve northward, and then end back at the jet axis. In general, this area should generously surround all the detectable highlights and shadows produced by convective clouds. It also should

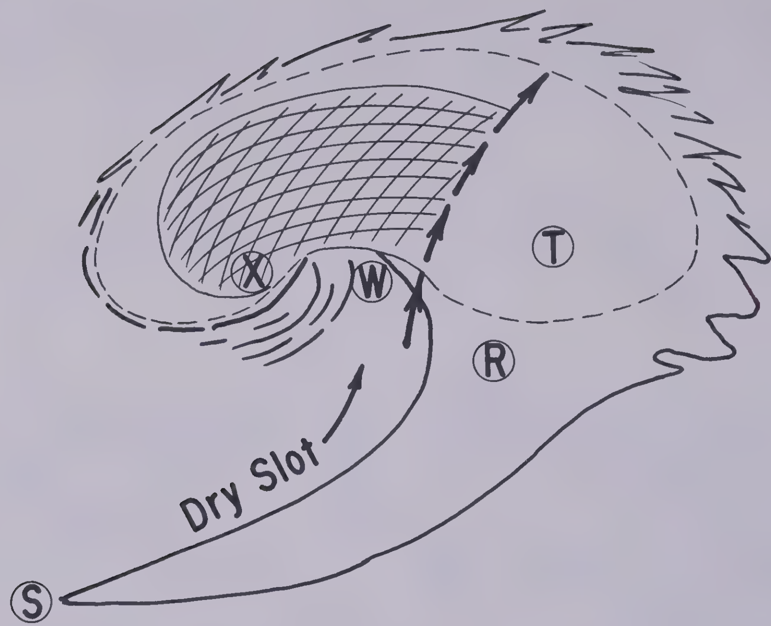

Figure 5. Schematic showing the location of precipitation in an East Coast cyclone.

have a configuration similar to the outer, dashed-line area west of the jet stream.

Figure 6 shows these important cloud features in an Atlantic storm. The frontal cloud band arcs from the storm center (H) to J and back toward I, and the jet axis lies along the cirrus cloud shadow (J). The textured appearance of the clouds west of the jet stream (K) is due to the sun highlighting the eastern side of the convective cells, and these clouds casting shadows toward the west on the surrounding lower cloud deck. The heaviest precipitation occurs in the convective cloud area K, west of the jet stream.

Not all satellite-viewed cloud patterns are this clear-cut, but most contain convective clouds through the east-west portion of the frontal band. Figure 7a shows the cloud pattern associated with the February 7, 1967, snowstorm. The jet stream axis lies along the poleward edge of the smooth cirrus shield (I-J). An area of convective clouds (K) can be seen west of the jet stream axis. Figure 7b shows the heaviest precipitation that occurred within 30 minutes of the satellite view. (Dashed line outlines entire area of precipitation, and solid line outlines area of expected heavy precipitation based on the satellite data.) Heavy to moderate snow was reported throughout the convective cloud area (K) and light snow through the remainder of the outlined area.

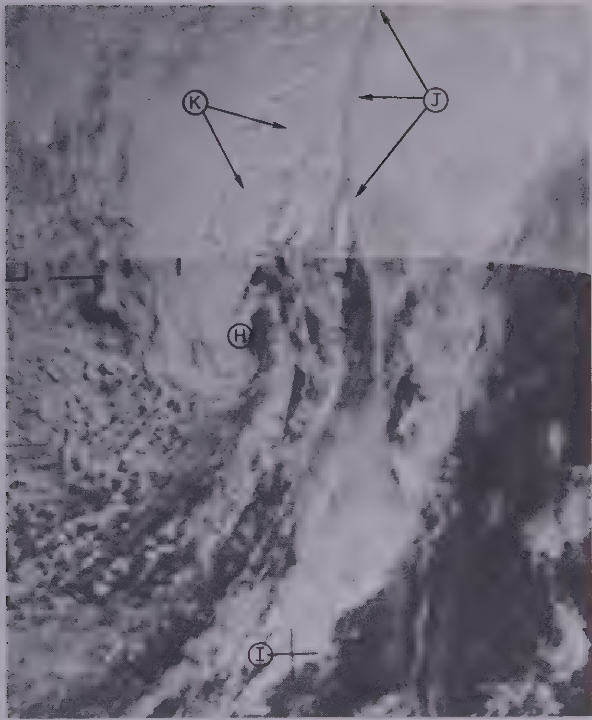

Figure 6. ESSA-8, Orbit 9175, 1322 GMT, December 16, 1970. An Atlantic storm.

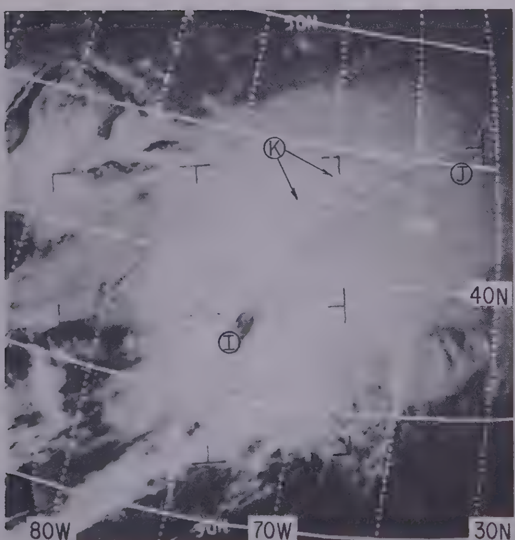

Figure 7a. ESSA-3, Orbit 1611, 1824 GMT, February 7, 1968.

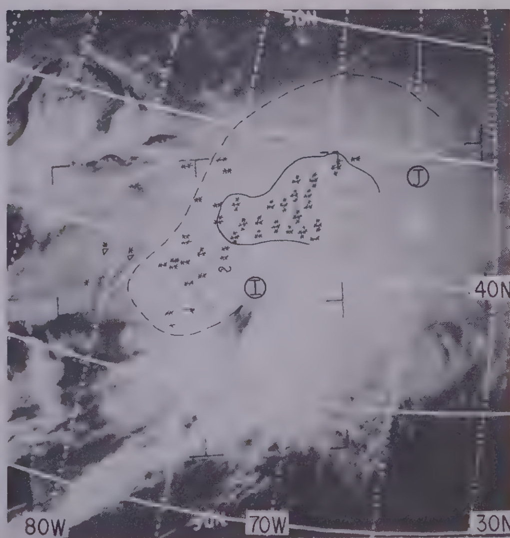

Figure 7b. Overlay showing the heaviest precipitation within 30 minutes of the photograph.

In the storm system shown in figure 8a, the transverse bands at I locate the position of the jet stream. The area of brighter, convective clouds appears to extend westward from K to L-M-N. Surface observations within 30 minutes of picture time indicate that the heaviest precipitation was occurring in the active area near K (figure 8b). In this case, the entire storm system, including the frontal band, is still over land. Moderate rain was reported along the North Carolina-Virginia coast from the frontal band (near I).

Effect of the Dry Slot on Precipitation

Knowing the position, size, and direction of movement of the dry slot is important to forecasting the end of the heaviest snow or rain. As shown in figure 5, the heaviest precipitation lies to the north and west of the dry slot. When this dry slot passes northward over a station, the heaviest precipitation will be over at that station. If the storm is moving in an easterly or northeasterly direction, more precipitation can be expected from the solid cloud area west of the dry slot. An increase in size of the dry slot can also terminate or reduce the intensity of the precipitation at a station.

In the examples shown in figures 9a and 9b, a storm was moving rapidly northward along the coast. In figure 9a, the X's locate the 1200 and 1800 GMT, November 12, and the 0000 GMT, November 13, analyzed surface positions of the low center. At 1458 GMT, November 12, 1968, the satellite data indicated the vortex center to be located at L, offshore and south of the Delmarva Peninsula. At this time, the dry slot (D) was affecting the precipitation from the New Jersey coast to the Delaware Bay. Only light rain was falling

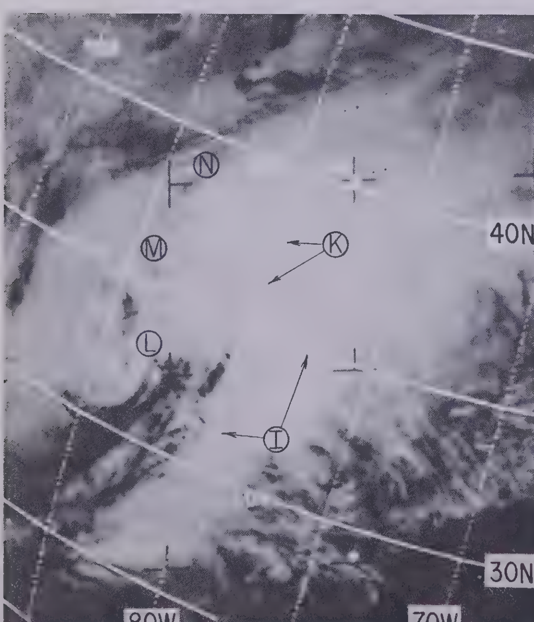

Figure 8a. ESSA-3, Orbit 3680, 1725 GMT, December 28, 1967.

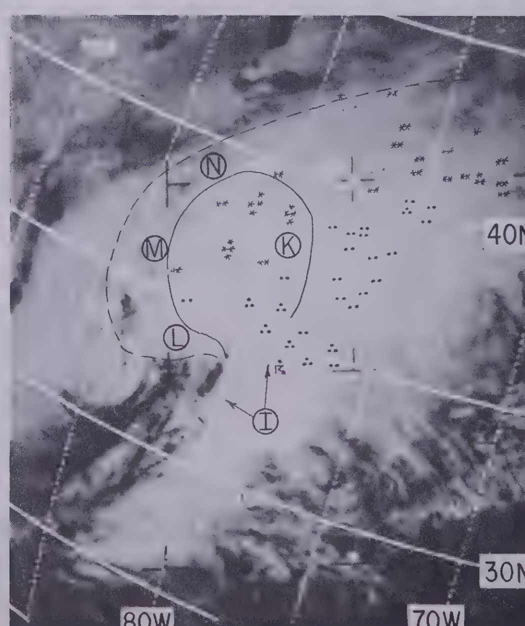

Figure 8b. Overlay showing heaviest precipitation within 30 minutes of satellite data. (For other markings, see text, figure 7b.)

in the area. Light rain was also reported in the area of smooth-topped stratiform clouds north of the dry slot along the Rhode Island, Connecticut, and New York coasts[3]. Farther south, a break can be seen in the vortex clouds along the eastern shore of the Delmarva Peninsula; no precipitation was being reported here. Heavy snow was falling throughout eastern Pennsylvania and New York, and in New England, where convective clouds (K) were present.

Figure 9b shows the storm four hours later. The storm center (L) was located off the New Jersey coast and the dry slot was south of Long Island. By this time the heaviest precipitation was occurring in New York, Vermont, New Hampshire, western Maine, and eastern Massachusetts. Light to intermittent precipitation was reported in the areas west and immediately to the north of the dry slot, with some very light precipitation still reported south of 40°N.

The 12-hour precipitation amounts reported at 0000 GMT, November 13, are shown in figure 9b. More than five inches of snow fell through large areas of New York, Pennsylvania, and New England. Rain was observed along the coast from the Carolinas to Maine and a mixture of rain, ice pellets, snow, and graupel in the areas between. Note the sharp change in rain

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3 A small isolated cluster of convective clouds near the eastern tip of Long Island (figure 9a) brought heavy rains to that area and was responsible for the larger accumulation shown in figure 9b.

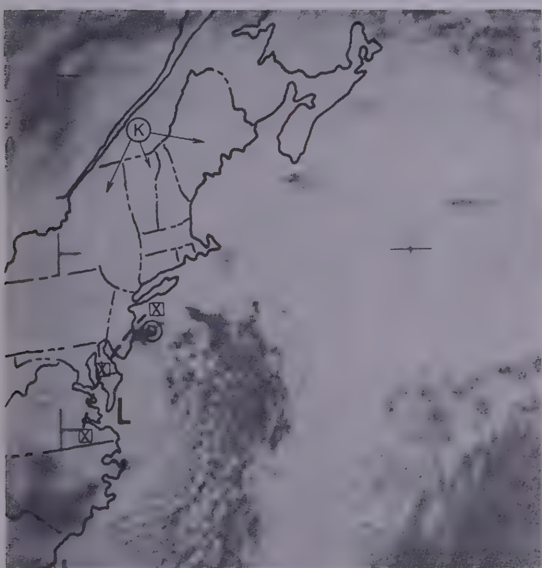

Figure 9a. ESSA-6, Orbit 4610, 1458 GMT, November 12, 1968.

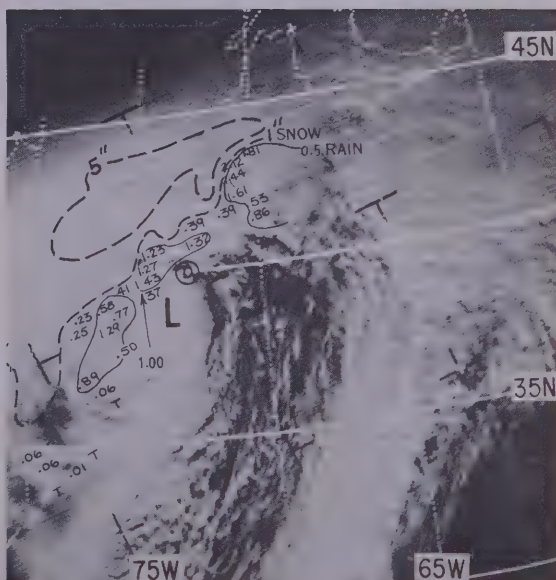

Figure 9b. ESSA-7, Orbit 1195, 1833 GMT, November 12, 1968.

accumulations in New Jersey; an accumulation of 0.37-inch was reported in the area where the almost clear dry slot was located in figure 9b, and accumulations of more than an inch were reported in the northern portion of the state where the more solid clouds were located. Another similar anomaly can be seen in southern New England. Here 0.39 to 0.86 inches of rain fell in southern New England where the less convective clouds were present, while 1.44 to 2.12 inches were reported farther north where the stations were under the more active portion of the storm during much of the day.

Precipitation from Vortex Bands

Some convective clouds which form due to surface heating may be present in the remaining cold-air vortex cloud bands behind the front. These clouds can produce locally heavy showers after the frontal band and dry slot have passed. Figure 10a shows the vortex structure of the February 10, 1969, storm. A number of convective cloud bands (P) can be seen in the vortex. Stations located under the vortex were reporting light snow or snow showers, figure 10b.

Figure 10a. ESSA-8, Orbit 714, 1415 GMT, February 10, 1969.

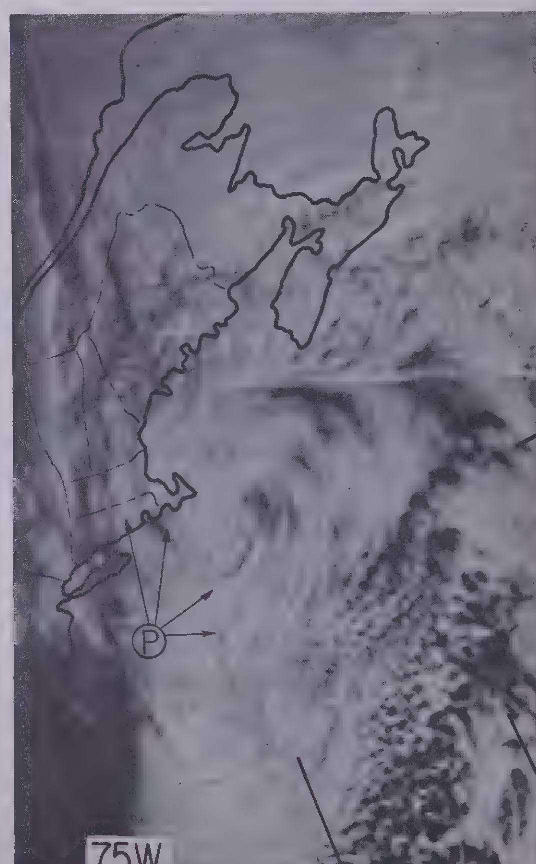

Figure 10b. Overlay showing precipitation within 30 minutes of picture time.

As the storm moves, the location of heavy precipitation generally remains in the same position relative to the storm center. Figures 11a to m illustrate this point.

Figures 11a, c, e, g, i, k show the available satellite views of the March 1-3, 1969, snowstorm. This storm first appeared offshore on March 1 and moved slowly up the coast. It remained almost stationary east of Virginia for nearly 12 hours, and then stalled for nearly 18 hours southeast of Long Island. Even though the center of the storm remained well offshore, heavy snow fell at many East Coast stations.

Figure 11g shows how each satellite view was analyzed. In this case, the position of the jet stream was not obvious; therefore a solid line was drawn about the bright and solid multilayered cloudiness; then a dashed line was drawn about the more active convective clouds north of the dry slot.

Figures 11b, d, f, h, j, l show the analyzed satellite data: the solid line outlines the general area of precipitation, the dashed lines outline the area where moderate to heavy precipitation would be expected, and the hatched area represents the area where moderate to heavy precipitation was reported within 30 minutes of the satellite picture time. A portion of the NMC-analyzed surface storm track is included on some of the maps. These satellite photographs indicated that precipitation would occur along the coast even though the center was well offshore. The actual observed heavy precipitation (figure 11m) and the extrapolation of the estimated heavy precipitation area are in good agreement.

Figure 11m shows the 24-hour accumulation patterns for March 1, 2, and 3. Much of the mid-Atlantic region received this precipitation over a period of 24 hours or more.

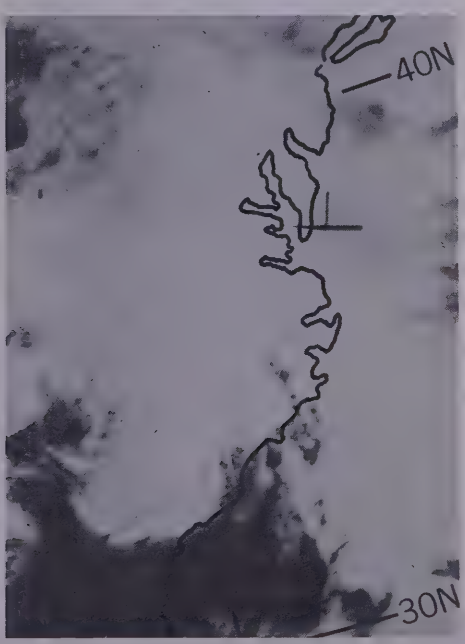

Figure 11a. ESSA-8, Orbit 953, 1407 GMT, March 2, 1969.

Figure 11b. Storm track, analyzed and observed precipitation patterns for ESSA-8 data.

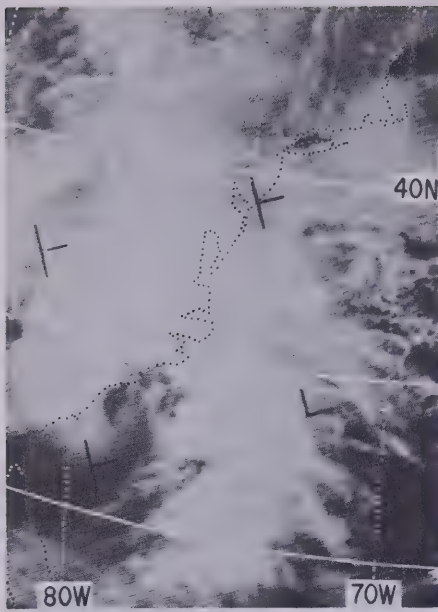

Figure 11c. ESSA-7, Orbit 2478, 1846 GMT, March 1, 1969.

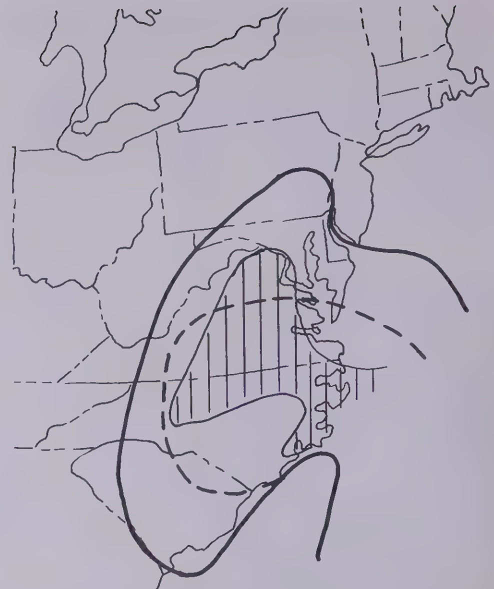

Figure 11d. Analyzed and observed precipitation patterns for ESSA-7 data.

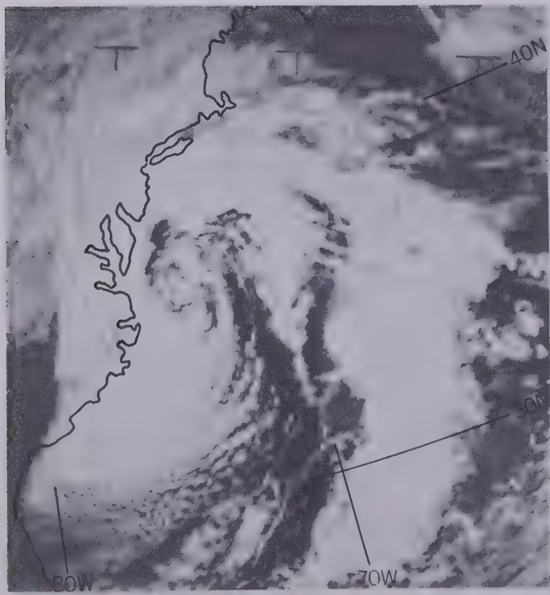

Figure 11e. ESSA-8, Orbit 965, 1407 GMT, March 2, 1969.

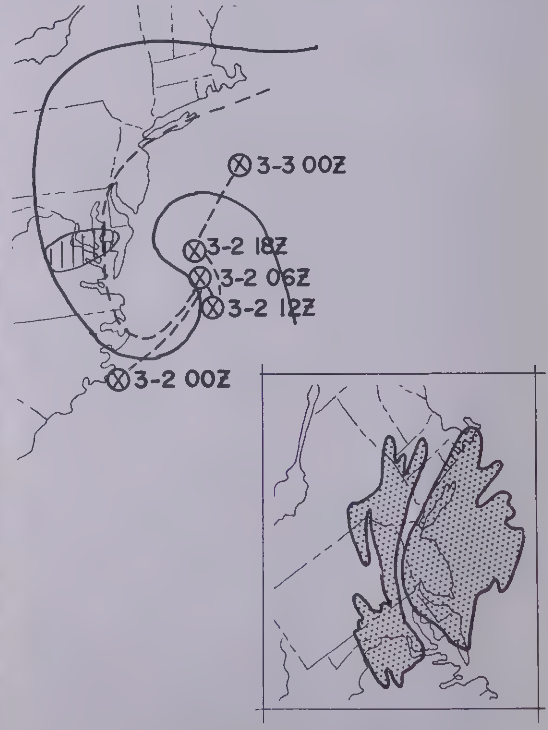

Figure 11f. Storm track, analyzed and observed precipitation pattern for ESSA-8 data. Stippled area - radar composite.

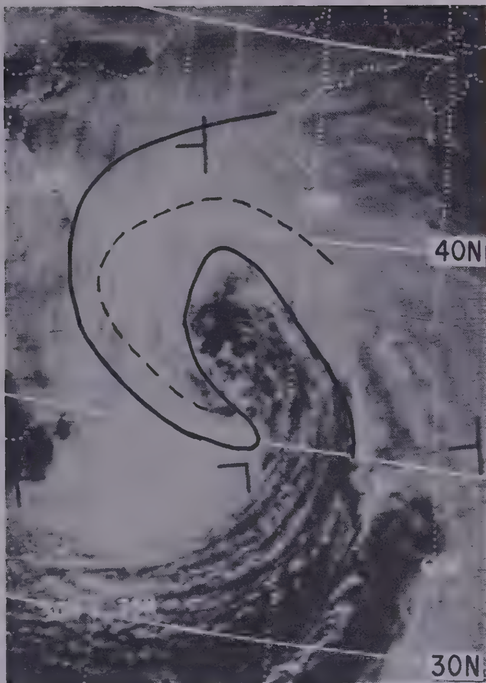

Figure 11g. ESSA-7, Orbit 2483, 1936 GMT, March 2, 1969.

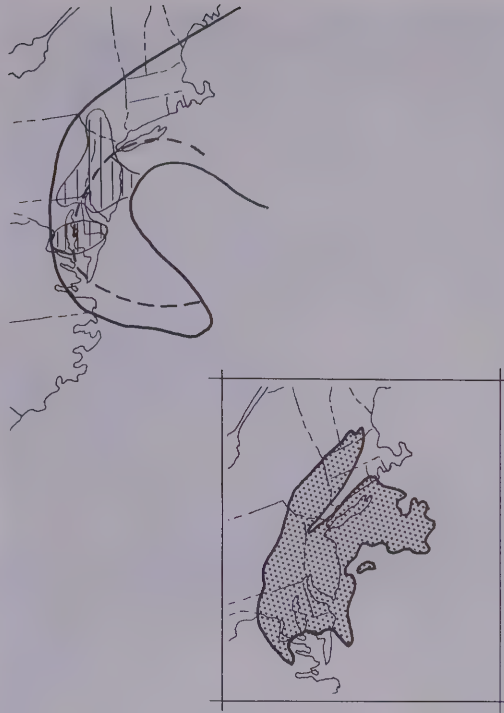

Figure 11h. Analyzed and observed precipitation patterns for ESSA-7 data. Stippled area - radar composite.

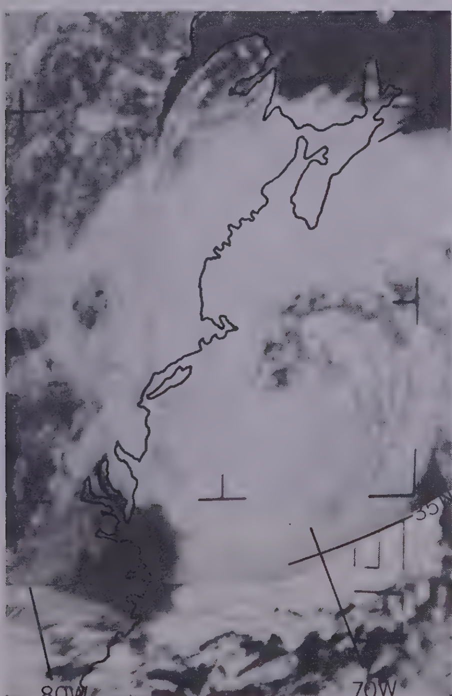

Figure 11i. ESSA-8, Orbit 978, 1505 GMT, March 3, 1969.

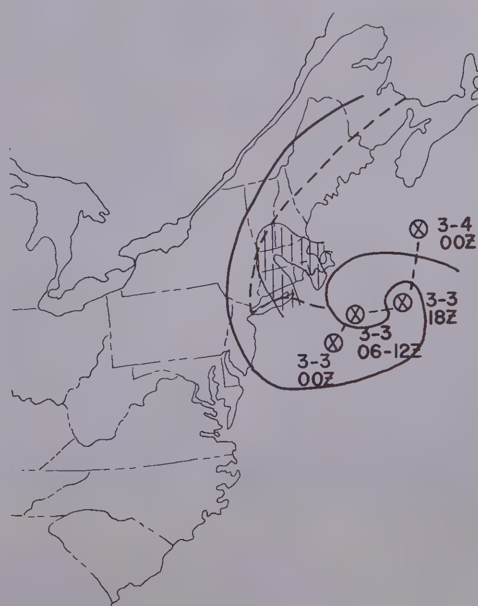

Figure 11j. Storm track, analyzed and observed precipitation patterns for ESSA-8 data.

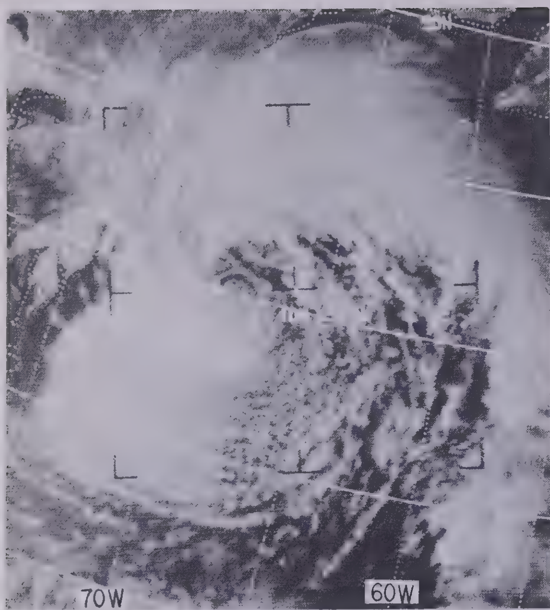

Figure 11k. ESSA-7, Orbit 2495, 1840 GMT, March 3, 1969.

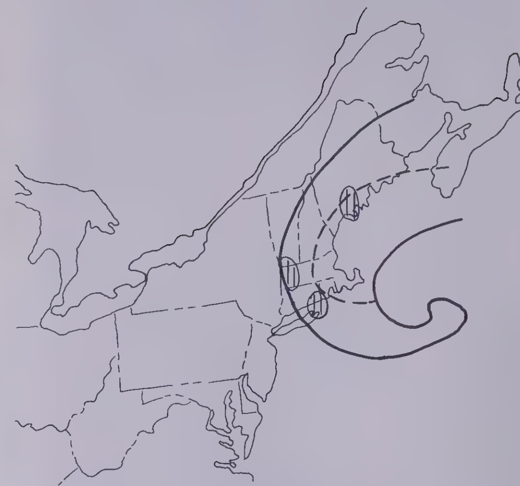

Figure 11ℓ. Analyzed and observed precipitation pattern for ESSA-7 data.

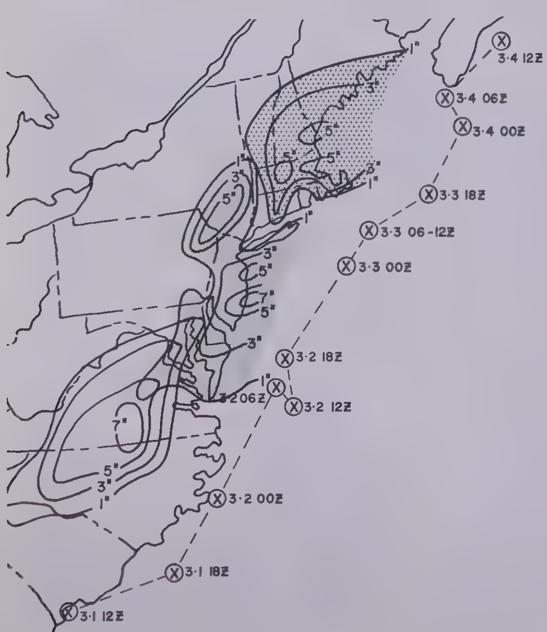

Figure 11m. Composite snow accumulation map, each shading representing March 1, 2, 3, 1969, respectively.

Composite radar maps were prepared for each corresponding satellite-view map. Radar data from Atlantic City, New Jersey, Washington, D. C., Pittsburgh, Pennsylvania, and New York were used. Since the correlation between a snow-intensity and radar reflectivity has not been established by the National Weather Service (Hamilton)[4], the first contour representing the 0 to 20-dB return was used to outline the radar echo. Radar data, used in conjunction with the satellite information, can assist in further pinpointing the movement of the most active cells within the storm. Large snow patterns are sometimes difficult to detect by radar. In this storm case, the best radar coverage was obtained on March 2 (stippled area, figures 11f, h) when the storm was within range of the coastal stations.

4 Correspondence dated December 7, 1970, from Robert Hamilton, Radar Meteorologist, National Weather Service Eastern Region.

In the future, infrared (IR) observations taken at frequent intervals will provide important nighttime views of cloud systems. Figures 12a and b show a nighttime IR view and daytime photograph (visible view) of the March 4, 1971 snowstorm. In the infrared display (figure 12a), the coldest radiating surfaces appear white and the warmest appear dark. In this view, the less cloudy dry slot area reaches northward to P. Higher, colder cirrus clouds associated with the jet stream can be seen crossing the frontal band at N. The heavy precipitation area lies to the west of the jet axis at O.

The position of the cirrus cloud edge is more difficult to detect in the APT picture (figure 12b) taken six hours later. In this view, the jet axis is placed along the edge of the smoother clouds (N). The other features which can be seen are the circulation center (L), the dry slot (P), and the convective cloud or heavy precipitation area which is clearly visible in the east-west portion of the vortex (O).

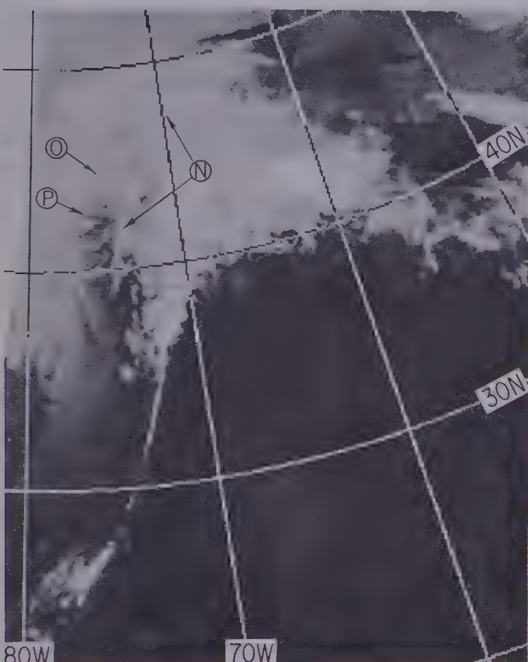

Figure 12a. ITOS-1, Orbit 5064, Nighttime IR, 0820 GMT, March 4, 1971.

Figure 12b. ESSA-8, Orbit 10155, 1449 GMT, March 4, 1971.

CONCLUSIONS

Satellite data provide answers to some of the East Coast snowstorm forecasting problems. They are most useful for detecting the initial stages of East Coast cyclogenesis and for tracking developing or mature storm systems. Certain features within the associated cloud pattern define the areas of heaviest precipitation and permit a more accurate prediction of the duration of heavy precipitation. The IR and visible data that will be available at frequent intervals from the GOES system will permit meteorologists to forecast more accurately the local short-term effects of these rapidly moving systems.

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Table 1. APT and AVCS pictures covering 15 East Coast storms from October 1966 through March 1969.

Date	APT Picture Time (GMT)	AVCS Picture Time (GMT)
12/13/66	1350	1908
12/14/66	1425	1805
12/23/66	1536	1801
12/23/66	1720	1951
12/24/66	1440	1656
12/24/66	1650	1850
12/25/66	1623	1747
2/6/67	1530	1734
2/6/67	----*	1929
2/7/67	1530**	1824
2/8/67	1530**	1725
2/8/67	----	1915
2/9/67	1530**	1810
2/10/67	1507	1707
2/10/67	----	1901
2/17/67	1526	1720
2/17/67	----	1910
2/18/67	1600	1806
3/5/67	1528	1915
3/6/67	1555	1811
3/7/67	1443	1710
3/7/67	----	1902
12/28/67	1445	1725
12/29/67	1350	1621
12/29/67	1558	----
1/13/68	1543	1729
1/14/68	1443	1625
1/14/68	----	1820
1/15/68	1535	1525
1/15/68	----	1715
1/16/68	1427	1615
1/24/68	1600	1710
1/25/68	1456	1607
1/25/68	----	1801
1/26/68	1355	1657
1/26/68	1600	----
2/29/68	1531	1751
3/1/68	1426	1548
3/1/68	----	1743
3/2/68	1523	1750
11/9/68	1608	----
11/10/68	1506	1842
11/11/68	1559	1742
11/11/68	1559	1934
11/12/68	1458	1838
11/12/68	1653	----
11/13/68	1551	1737
12/14/68	1450	1908
12/14/68	1640	----
12/15/68	1540	1812
12/16/68	1443	1903
12/16/68	1638	----
2/8/69	1429	1850
2/8/69	----	2040
2/9/69	1325	1744
2/9/69	1520	1935
2/10/69	1416	1838
2/23/69	1353	1901
2/23/69	1542	----
2/24/69	1440	1801
2/24/69	----	1956
2/25/69	1341	1856
2/25/69	1530	----
2/26/69	1436	1756
2/26/69	----	1951
2/27/69	1329	1851
3/1/69	1505	1846
3/2/69	1405	1941
3/3/69	1500	1840
3/4/69	1345	1745

*On some dates, two passes covered the storm area. When only two AVCS passes cover the storm, the APT list will be blank and vice versa.

**Approximate times - time data missing.

Table 2. East Coast observing network stations and call letters

Maine

Caribou	CAR
Portland	PWM
Dow-Bangor	BGR
Loring	LIZ
Brunswick	NHZ

Vermont

Burlington	BTV

Rhode Island

Block Island	BID
Providence	PVD
Quonset Point	NCO

New York

Albany	ALB
Binghampton	BGM
Buffalo	BUF
JFK Airport	JFK
La Guardia	LGA
Rochester	ROC
Syracuse	SYR
Plattsburgh AFB	PLB
Stewart (Newburgh)	RME
Suffolk Co. (Navy)	FOK
Floyd Bennett Field (Navy)	NSC

Virginia

Lynchburg	LYH
Norfolk	ORF
Richmond	RIC
Roanoke	ROA
Wallops Island	WAL
Langley AFB	LFI
Felker - Ft. Eustis	FAF
Virginia Beach	NTU
Quantico	NYG
Ft. Belvoir	DAA

New Hampshire

Concord	CON
Pease AFB	PSM
Grenier	MHT

Connecticut

Bridgeport	BDR
Hartford	EHT
New Haven	HUN

Massachusetts

Boston	BOS
Nantucket	ACK
Worcester	ORH
Otis AFB	FMH
Westover AFB	CEF
Hanscom Field	BED
South Weymouth	NZW

New Jersey

Atlantic City	ACY
Newark	EWR
McGuire AFB	WRI
Lakehurst	NEL

Delaware

Wilmington	ILG
Dover	DOV

North Carolina

Asheville	AVL
Cape Hatteras	HAT
Charlotte	CLT
Greensboro	GSO
Raleigh	RDU
Simmons - Ft. Bragg	FBG
Pope AFB	POB
Seymour Johnson	GSB
Cherry Point	NUT
Jacksonville	W88
Wilmington	ILM

Maryland

Baltimore	BAL
Patuxent (Navy)	NHK
Tipton-Ft. Meade	FME

District of Columbia

Dulles	IAD
Washington National	DCA

Pennsylvania

Philadelphia	PHL
Harrisburg	HAR
Erie	ERI
Allentown	ABE
Wilkes-Barre	AVP
Pittsburgh	PIT
Williamsport	IPT
Willow Grove	NXX
Olmstead	OLM

West Virginia

Beckley	BKW
Charleston	CRW
Huntington	HTS
Elkins	EKN

(Continued from inside front cover)

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